STRUCTURAL SANDWICH CONSTRUCTION

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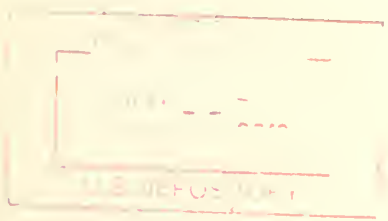

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FOREST SERVICE
FOREST PRODUCTS LABORATORY
Madison 5, Wisconsin
In Cooperation with the University of Wisconsin

STRUCTURAL SANDWICH CONSTRUCTION

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Structural sandwich construction is a laminar construction formed by bonding two thin facings to a thick core. The thin facings are usually of a strong, dense material, since they are the principal load-carrying portions of the construction. The core, which is of a weaker, lightweight material, separates and stabilizes the thin facings and carries shearing loads. The entire assembly provides a structural element of high strength and stiffness in proportion to its weight. Sandwich construction is also economical, since only small amounts of the relatively expensive facing material are used and the core materials are usually inexpensive. The materials are positioned so that each is used to its best advantage.

Specific nonstructural advantages can be incorporated in a sandwich construction by proper selection of facing and core materials. An impermeable facing can be employed to act as a moisture barrier for a wall or roof panel in a house; an abrasion-resistant facing can be used for the top facing of a floor panel; and decorative effects can be obtained by using panels with plywood or plastic facings for walls, doors, tables, and other furnishings. Core material can be chosen to provide thermal insulation and fire resistance.

The component parts of the sandwich construction should be compatible with service requirements. Moisture-resistant facings, cores, and adhesives should be employed if the construction is to be exposed to adverse moisture conditions. Similarly, heat-resistant or decay-resistant facings, cores, and adhesives should be used if exposure to elevated temperatures or decay organisms is expected.

Structural Design of Sandwich Construction

The structural design of sandwich construction may be compared to the design of an I-beam; the facings of the sandwich represent the flanges of the I-beam, and the sandwich core represents the I-beam web. The core of the sandwich serves, through the bonding adhesive, to carry shearing loads and to support the thin facings against lateral wrinkling caused by compressive loads in the facings.

In general, the procedure is to provide facings thick enough to carry the compression and tension stresses and then to space the facings with a core thick

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[1] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

enough to impart stiffness and bending strength to the construction. The core should be strong enough to carry the required shearing loads. The construction should be checked for possible buckling, as for a column or panel in compression, and for possible wrinkling of the facings.

The core material itself is assumed to contribute nothing to the stiffness of the sandwich construction, because it usually has a low modulus of elasticity. The facing moduli of elasticity are usually at least 100 times as great as the core modulus of elasticity. The core material may also have a small shear modulus. This small shear modulus causes increased deflections of sandwich constructions subjected to bending and decreased buckling loads of columns and edge-loaded panels, compared to constructions in which the core shear modulus is large. The effect of this low shear modulus is greater for short beams and columns and small panels than it is for long beams and columns and large panels.

The stiffness of a strip of unit width of sandwich construction having facings of equal or unequal thickness is given by:

$$D = \frac{f_1 f_2 E_1 E_2 (h + c)^2}{4(f_1 E_1 + f_2 E_2)}$$

where

D = stiffness per unit width of sandwich construction (product of modulus of elasticity and moment of inertia of the cross section)

f_1, f_2 = facing thicknesses

E_1, E_2 = moduli of elasticity of the facings

h = total sandwich thickness

c = core thickness

The stiffness is used to compute the deflections and the buckling loads of sandwich panels.

The midspan deflection of a panel of sandwich construction, with simply supported ends and free edges, under a uniform transverse load is given by:

$$w = \frac{5Pa^3}{384Db}\left[1 + \frac{192\,cD}{5a^2 G_c (h + c)^2}\right]$$

where

w = midspan deflection

P = total load on sandwich panel

a = span length

G_c = shear modulus of core material

b = width of sandwich panel

In a strip of sandwich construction subjected to both bending moments and shear loads the mean facing stresses are given by:

$$S_{1,2} = \frac{M}{f_{1,2}(h + c)b}$$

where

$S_{1,2}$ = mean compression or tension stress in facing 1 or 2

$f_{1,2}$ = thickness of facing 1 or 2

M = bending moment

Under the same conditions, the shear stress in the core is given by:

$$q = \frac{2V}{(h + c)b}$$

where

q = shear stress in the core

V = shear load on the sandwich

The buckling load of a sandwich panel at least twice as wide as it is thick and loaded as a simply supported column is given by:

$$P = \frac{\pi^2 Db}{a^2\left[1 + \frac{4\pi^2 cD}{a^2(h + c)^2 G_c}\right]} \quad \text{for} \quad \frac{4\pi^2 cD}{a^2(h + c)^2 G_c} < 1.0$$

and

$$P = bh\,G_c \quad \text{for} \quad \frac{4\pi^2 cD}{a^2(h + c)^2 G_c} \geq 1.0$$

where

a = column length

b = panel width

The preceding formulas are basically those needed for the design of sandwich constructions. Formulas have been derived for various loading and edge conditions for constructions of orthotropic or isotropic materials. The behavior of thin facings in regard to wrinkling and core shear failure has also been investigated. Analyses of these more specific problems of design may be found in references (1, 2, 3, 5, 6, 7, 9).[2]

Manufacture of Sandwich Construction

The principal operation in the manufacture of sandwich construction is the bonding of the facings to the core. The bonding operation may involve the use of a hot press if pressure and elevated temperature are needed to cure the adhesive. Light pressures should be used for weak core materials to prevent them from crushing. Some adhesives may require only contact pressure and no heating. The process should be controlled to obtain good facing-to-core bonds, since poor bonding materially reduces stiffness as well as strength.

The facing materials may need to be cleaned and primed before the adhesive is applied, especially if they are metallic.

The core material may need to be formed and bonded together before the facings can be applied. Some core materials may need a glue size before good bonding to the facing can be obtained.

In certain sandwich panels, loading rails or edgings are placed between the facings at the time of assembly. Special fittings or equipment, such as heating coils, plumbing, or electrical wiring conduit, can be placed more easily in the panel during manufacture than after it is completed.

Further information on fabrication procedures for different kinds of sandwich construction is given in references (4, 8, 10).

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[2] Underlined numbers in parentheses refer to Literature Cited at end of this report.

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